PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : B03C 3/53

A1

(11) International Publication Number: WO 98/58743

(43) International Publication Date: 30 December 1998 (30.12.98)

(21) International Application Number: PCT/US98/12596

(22) International Filing Date: 16 June 1998 (16.06.98)

(30) Priority Data: 08/880,354 23 June 1997 (23.06.97) US

(81) Designated States: CA, IL, JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(71) Applicants: CORONA CATALYSIS CORPORATION [US/US]; 3200 George Washington Way, Richland, WA 99352 (US). BATTELLE MEMORIAL INSTITUTE [US/US]; Pacific Northwest Division, Intellectual Property Services, P.O. Box 999, Richland, WA 99352 (US).

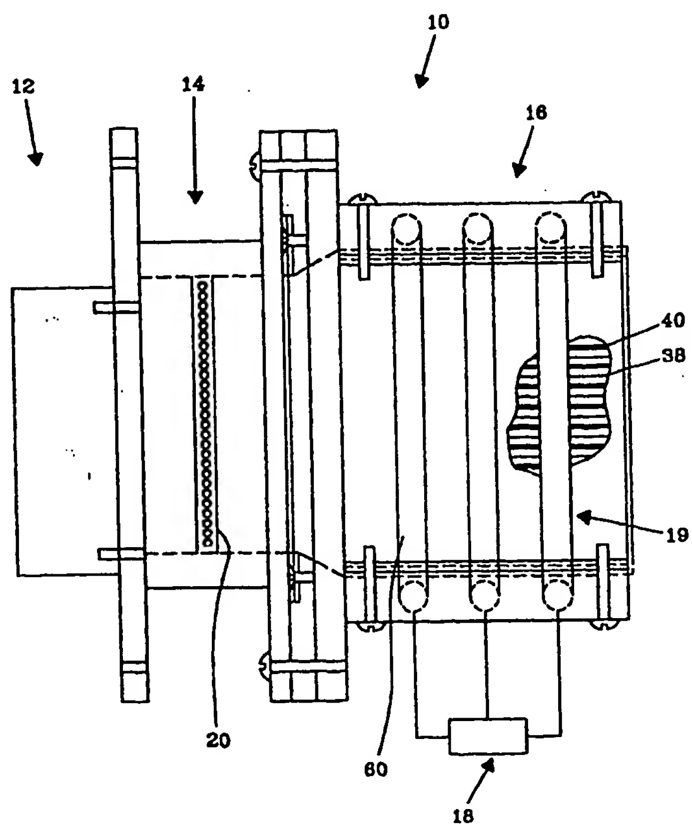
(72) Inventors: IRVING, Patricia, M.; 5050 South Olympia Street, Kennewick, WA 99337 (US). BIRMINGHAM, Joseph, G.; 2500 George Washington Way, Richland, WA 99352 (US). HAMMERSTROM, Donald, J.; 3203 Mt. Daniel, West Richland, WA 99353 (US). CALL, Charles, J.; 3807 Meadow View Court, Pasco, WA 99301 (US).

(74) Agents: SAKOI, Jeffrey, M.; Christensen, O'Connor, Johnson & Kindness PLLC, Suite 2800, 1420 Fifth Avenue, Seattle, WA 98101 (US) et al.

(54) Title: ELECTROSTATIC PRECIPITATOR

(57) Abstract

The invention comprises an electrostatic precipitator capable of separating sub-micron size particulate matter from a gaseous stream. In a preferred embodiment, alternating high voltage plates and ground collector plates are placed in a particular laden gas stream. The collector plates are provided with a plurality of micro-machined channels therein aligned generally perpendicular to the flow of gas through the device. The channels are provided with a liquid flowing therethrough to collect and concentrate the particulates collected therein. Analytical means may be provided to analyze the particulate matter thus collected.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

ELECTROSTATIC PRECIPITATOR

This invention was made with Government support under Contract DAAM01-97-M-0006 awarded by the U.S. Department of Defense. The Government has certain rights in this invention.

BACKGROUND OF THE INVENTION

The capture of particulate matter or aerosols in air or other fluid streams is important as an analytical tool to determine the type and concentration of such particulate/aerosol material, and also potentially as a method of cleansing the fluid stream of the particulate matter for subsequent use. For example, the detection of airborne biological or chemical warfare agents, the detection of biological contamination in confined spaces such as aircraft or hospitals or the detection of industrial pollutants (either in ambient air or in stacks) may be required in various and different scenarios.

Much effort has been expended in the past in the detection and classification of particulate matter or aerosols, generally in air or other gaseous streams. Numerous devices have been used to effect such separation, such as virtual impactors, electrostatic precipitators, and the like. Electrostatic precipitators have been well known for years and much effort has been expended for their optimization. The art of collecting charged particles on collector plates in electrostatic precipitators is in a high state of development, as evidenced by the many patents issued in the area. For example, U.S. Patent No. 5,626,652 discloses an electrostatic precipitator using laminar flow to remove sub-micron size particles from a gas stream. Particles

are charged and collected in a plurality of tubular members electrically coupled to a potential of opposite polarity to that of the particles.

Likewise, in U.S. Patent No. 5,477,464, a pulsating current in an electrostatic precipitator enables one to obtain a plurality of combinations of frequency, charge and duration. In U.S. Patent No. 5,429,669, oily dusty particles are precipitated on large and small electric plates, and scrapers are mounted therebetween to remove the particulate matter, with a collecting unit underneath to collect the particles. As these and other patents illustrate, the collection of charged particulate matter in electrostatic precipitators is relatively easy to accomplish. However, the collection of such particles, once precipitated, is a matter of much research, especially in the search for the optimum collection medium. For example, in U.S. Patent No. 5,334,238, a stream of cleaning gas is directed through a flexible tube that randomly is directed across the surface of precipitator plates with sufficient force to dislodge particles adhered thereto. Liquids have been used in such cases, as in U.S. Patent No. 5,084,072, wherein a constant liquid stream is maintained over the inside surface of a glass collector tube and a discharge electrode into which the particulate matter is directed.

As illustrated in U.S. Patent No. 5,015,267, mechanical energy has been used to dislodge the particulate matter from the collector plate, as with the use of rappers. High velocity air has been used to clean particulate matter from collector plates, as in U.S. Patent No. 4,861,356.

Numerous types of particulate matter is of interest in such systems. The need for accurate and reliable biological warfare detector/collection systems emerged from the Desert Storm conflict as a means of protecting

troops (and others) in close proximity to biological agents. However, biological weapons are not limited solely to warfare—as was evidenced by the Tokyo subway attack by the Aum Shinrikyo cult, where the chemical agent sarin was released in the Tokyo subway. Air quality monitoring is of critical importance as a means of conventional public health assessments, both as a means of detecting but also providing warnings of high levels of airborne particulates. Recirculation of air in buildings as indoor pollution causes worker illness (the "sick building syndrome"). Nosocomial, or hospital-acquired, infections are often caused by antibiotic resistant microorganisms spread throughout the hospital in air-handling systems or in ambient air caused by movement between rooms by hospital personnel. Finally, the determination of particulate matter in, for example, stack gases, can be an early warning of potential pollutant releases, and of process efficiency upstream from the stack.

In each of these environments, it is of interest to know not only the quantity but quality of the airborne particulates. The ability to accurately measure the various constituents is important, but in the past the ability to make such determinations has been negated by the large size and relatively high power requirements of the devices. Devices capable of being worn by individuals would greatly expand the ability to offer personal protection to soldiers, workers, and the like. However, prior to the present invention, the technology had not progressed to the point of pocket-sized electrostatic precipitation detection devices.

BRIEF SUMMARY OF THE INVENTION

The present invention comprises an electrostatic precipitator device especially adapted to remove very small charged particulate matter from a moving gas stream, and in particular, an air stream. The device comprises a plurality of high voltage electrode plates alternating with a plurality of ground electrode plates with a liquid flowing thereon. Charged particulate matter in the air stream is attracted to the ground electrode plates and collected on the liquid flowing thereon. The voltage applied to the high voltage plates may be continuous or pulsed. The liquid stream having particulate matter is concentrated for subsequent analysis.

Additionally, the device may include a fan to move, the gas stream through the device, a charging member to impart an electrical charge to the particulate matter in the gas stream, a plurality of both high voltage and ground plates alternating with one another, a collection/concentration fluid, and analytical means to analyze the particulate matter collected.

The ground electrode plates are preferably micro-machined with a plurality of micro-channels therein, with the channels arranged in the device perpendicular to the direction of flow of the gaseous stream. The micro-channels are at least partially filled with the liquid, which concentrates the particulate matter in a relatively small volume. The liquid circulates through the device, effectively "cleansing" the micro-channels of particulate matter. The liquid may be induced to flow through the micro-channels by gravity, or it may wick through the micro-channels by surface tension, or by any other process. Analysis of the particulate-laden liquid may be off-line, in continuous or batch mode, by separate well-known analytical tools, or by in-line micro-detectors.

The apparatus of the present invention enables predictability in collection, increased sensitivity, and relatively high throughput for devices so small. Whereas devices previously known had relatively high power requirements, miniaturization of the components of the present invention substantially reduce the power requirements and enable long-life battery operation. Through the incorporation of microfluidics (the application of microfabrication techniques to the construction of individual components or integrated systems, the devices of the present invention exhibit sensitivity not possible with prior art devices.

The apparatus of the present invention is not limited to any particular structural configuration. For example, the liquid flow through the microchannels of the device may be by gravity or by wicking, the ground plate with the microchannels therein may be coated so as to enhance collection of particulate matter in the fluids, and the like.

While the ultimate separation characteristics of the present invention have not yet been fully determined, the device is capable of separating in excess of 90% of the particulate matter of interest in a given gaseous fluid stream.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view of a preferred embodiment of the electrostatic precipitator device of the present invention;

Fig. 2 is a side view of the charging element of the present invention;

Fig. 3 is a side view of the separation/collection section of a preferred embodiment of the present invention;

Fig. 4 is a schematic representation of a partial sectional of the high voltage plate and the ground collector plate of the present invention;

Fig. 5 is an enlarged view of a portion of the ground collector plate of the present invention;

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 is a plan view of the apparatus of the present invention. While the embodiment represented by Fig. 1, and the subsequent figures, represents a preferred embodiment, it is to be understood that such figures represent merely a single embodiment, and numerous other embodiments, not set forth herein, will be readily apparent to those of ordinary skill in this art.

In Fig. 1, the device 10 comprises, generally, a fan 12, charging section 14, and separation/collection section 16 with alternating high voltage electrode plates 38 and ground collector plates 40. It will be apparent to one of skill in the art that a fan may not be needed if the particulate laden gaseous fluid is either moving (e.g. wind), or the device 10 is moving (e.g. mounted on a vehicle). A separate analytical section is illustrated schematically at 18, although the actual placement of the analytical section is not critical to the operation of the device 10. A liquid supply system 19 has supply headers 60 supplying liquid to the collector plates 40. It is to be understood that the device illustrated in the figures herein is a prototype device that adequately illustrates the principles of the present invention, and that upon miniaturization the actual configuration of various parts may change, although their function will remain as illustrated and described herein.

The fan 12 may be of any design which is subject to miniaturization, which will move sufficient quantities of

the gaseous fluid. As illustrated in Fig. 1, the fan is in a "pusher" configuration to push air through the electrostatic precipitator device—it could also be located downstream of the collection unit 16 so as to "pull" the gaseous fluid through the device.

The charging section 14 comprises a member that will impart a charge to the particulate matter in the gaseous fluid. As further illustrated in Fig. 2, the charging element 20 of the charging section 14 is comprised of a plurality of alternating ground 22 and high voltage 24 wires, with spaces 5 therebetween so as to permit passage of the gaseous fluid stream. While the charging element 20 may be constructed of many individual wires, Applicants have found that the device may be advantageously constructed of a single ground wire and a single high voltage wire threaded through apertures 26 in upper and lower retaining members 28, 30 respectively. For example, in the embodiment of Fig. 2, the spacings of apertures 26 may be 0.1", and the wires 22,24 may be 15 mil (0.38 mm) coated copper. Spacings between wires are therefore about 0.05" (1.27 mm). It will be apparent to one of skill in the art that the charging section 14 is not needed if the particulate of interest of already charged. The size and spacing of the wires permit charging particles at voltages below which corona dischage occurs. Particles may also be charged at voltages sufficient to produce corona discharge, but lower voltage particulate charging is preferred.

The separation/collection section 16 of the present invention (Fig. 3) comprises a frame member 31 having a pair of side members 32, a top 34 and bottom 36. In the embodiment of Fig. 3, alternating high voltage electrode plates 38 and ground electrode collector plates 40 are placed adjacent one another with spaces 46 therebetween to permit flow of the gaseous medium therethrough. Each

of the high voltage electrode plates 38 is interconnected to a high voltage electrode 42, and each of the ground electrode plates 40 is interconnected to a ground electrode 44.

Each of the ground collector plates 40 is provided with a plurality of micro-channels 48 therein. As illustrated schematically in **Fig.** 4, a plurality of micro-channels 48 are provided in each side of each collector plate 40. Particulate laden gaseous fluid (represented by arrows 50) passes between the plates 38, 40, and flows through the device substantially perpendicular to the micro-channels, and to the movement of fluid within the micro-channels.

Referring again to **Fig.** 1, in a preferred embodiment the separation/collection section 16 is provided with a liquid supply system 19 to apply a film of liquid to each side of the ground collector plates 40. As illustrated in **Fig.** 1 the liquid supply system may comprise a plurality of supply headers 60 that overlie the collector plates 40. The supply headers 60 are provided with apertures (not shown) that, in the embodiment of **Fig.** 1, supply liquid by gravity to the top of collector plates 40. As further illustrated in **Fig.** 3, the supply headers 60 may be an upper 62 and lower 64 header supplying liquid to the collector plates 40 through apertures 66.

While the embodiment of **Figs.** 1 and 3 illustrates the supply of liquid to the surfaces of the ground collector plate by gravity, it is to be appreciated that with appropriately configured and sized micro-channels, the micro-channels may be capable of wicking the fluid by capillary action throughout the length of the micro-channel, thereby making the device operative irrespective of orientation. In any event, a micro-pump will be

required to ensure circulation of the fluid throughout the device.

Analytical capabilities may be provided with the present invention. While the device may be constructed to merely separate, collect and concentrate particulate matter in a liquid (for subsequent dismantlement and analysis), the device may also be constructed with integral analytical capabilities. As illustrated schematically in the Figures, an analytical section may be provided integral to the collection system so that immediate on-line, real time analysis is possible.

The quantity of liquid supplied to the micro-channels will be a design feature dependent on the particular circumstances. In some cases, it may be advantageous to ensure sufficient liquid to entirely fill the micro-channels and create a meniscus 66 (Fig 5) extending beyond the land area 68 of each collector plate.

The various plates can be coated with appropriate coatings to ensure maximum collection of particulate matter. For example, by putting a hydrophillic coating within each micro-channel 48, and a hydrophobic coating on the land area 68 between micro-channels or on the high voltage electrode, wetting of only desired surfaces can be achieved.

While not critical to the present invention, laminar flow of liquid through the micro-channels will maximize separation and collection of particulate matter. Applicants have found that collection efficiencies increase with laminar, as opposed to turbulent, flow.

It is anticipated that in order to clean the collector plate, one may wish to reverse the polarity of the plates, thereby inducing particulate matter adhered to the ground plate to thereafter move to the former high voltage plate, now the ground plate.

Applicants have found that the present invention is so efficient, most of the collection of particulate matter occurs in the "upstream" portion of the collector plates, nearest to the charging element. While this indicates that smaller collector plates are therefore possible, it is possible to overload the initial micro-channels with particulate matter. Therefore, by pulsing the current through the high voltage plates sequentially (e.g. the upstream 1/3 first, the middle 1/3 next and the most downstream 1/3 last), the entire surface of the collector plates will be subjected to maximum collection.

EXAMPLE

(a) Experimental Design: A device according to Figure 1 was constructed, with the design criteria that it must be capable of processing in excess of 1000L of an ambient air stream per minute. The prototype contained collector plates without micro-channels machined therein. Power applied to the prototype was 600 volts and 5×10^{-6} amps, resulting in a fraction of a Watt. An aerosol of fluorescent polystyrene latex (PSL) microspheres was generated in a nebulizer. Microsphere sizes ranging from 0.2 to 5.5 micrometer in diameter were tested. The PSL solution was nebulized in a Retec nebulizer with a 30 mL reservoir volume, operating at a nominal pressure of 20 psig. The flow rate from the nebulizer was between 2.5 and 3.0 LPM. Particulate concentration of between 10^5 to 10^6 per L was achieved. A Coulter Counter and fluorometer were used for liquid phase concentration determinations. A Sequoia Turner model 450 fluorometer was used to measure the fluorescence of liquid samples. Measured fluorescence was scaled by the fluorescence from a standard solution of microspheres. Each standard contained a known number density of microspheres,

enabling the number density in the sample to be determined.

(b) Results: Collection efficiency with a non-machined collector plate exceeded 70%. It is anticipated that efficiency with a full complement of micro-machined channels will increase the efficiency to well in excess of 90%.

TABLE 1

Particle Size (micrometer)	Ave Collection Efficiency (%)
0.485	84
0.752	72
0.930	77
0.973	90
1.871	71

(b) In a separate test, a collector plate was machined with micro-channels 1 mm in depth and a width of 150 micrometers. Wicking (capillary) water flow through the micro-channels to a distance exceeding 15 cm was accomplished, thereby reducing power requirements for a micro-pump.

The present invention and a preferred embodiment has been particularly described herein. It is to be understood that the scope of the invention is not to be limited by the scope of the description herein, since it will be readily apparent to those of ordinary skill in this art that many modifications and improvements can be made to this invention without departing from the spirit and scope of the invention. Accordingly, the scope of the present invention should be limited solely by the scope of the claims appended hereto.

We claim:

1. An electrostatic precipitator device to remove charged particles from a moving gaseous fluid stream, said device comprising:

a. a plurality of high voltage electrode plates alternating with a plurality of ground electrode collector plates, with a continuous voltage applied to the high voltage electrode plates;

b. a liquid in continuous flow over the ground electrode collector plates to collect charged particles attracted to the collector plates.

2. The device of Claim 1, further comprising a particulate charging member for providing the charged particles.

3. The device of Claim 2, wherein the moving gaseous fluid stream is moved through the device by a fan.

4. The device of Claim 2, wherein the particulate charging member comprises a plurality of high voltage wires alternating with a plurality of ground wires.

5. The device of Claim 1, wherein the ground electrode collector plates are provided with a plurality of micro-channels on each surface thereof.

6. The device of Claim 5, wherein the liquid is provided in laminar flow over the collector plates.

7. The device of Claim 6, wherein the micro-channels are provided in a direction substantially

perpendicular to the direction of the gaseous fluid stream moving through the device.

8. The device of Claim 7, wherein the voltage is applied continuously to the high voltage electrode plates.

9. The device of Claim 7, wherein the voltage is applied sequentially to the high voltage electrode plates.

10. The device of Claim 7, wherein the charged particles are collected in the liquid, and analytical means are provided to analyze the charged particles in said liquid.

11. The device of Claim 1, wherein the polarity of the plates is reversed, such that the high voltage electrode plates are ground plates and the ground electrode collector plates are high voltage plates, thereby inducing particulate matter adhered to the ground plates to move to the high voltage plates.

12. An electrostatic precipitator device to remove charged particulate matter from a moving gaseous fluid stream, said device providing continuous movement of the gaseous fluid stream therethrough and a continuous voltage applied thereto, said device comprising;

a. an air moving device to ensure movement of the gaseous fluid through the device;

b. a plurality of high voltage electrode plates alternating with a plurality of ground electrode collector plates, with a continuous voltage applied to the high voltage electrode plates;

c. a particulate charging member upstream of the plurality of plates for imparting a charge to each of the particles in the gaseous fluid stream;

d. a liquid fluid reservoir providing a continuous flow of liquid over the collector plates to collect charged particles deposited on the collector plates; and

e. an analytical means to analyze the particulate matter collected in the liquid.

13. The device of Claim 12, wherein said air moving device comprises a pump.

14. The device of Claim 12, wherein said ground electrode collector plates are provided with a plurality of micro-machined channels substantially perpendicular to the continuous movement of the gaseous fluid stream.

15. The device of Claim 14, wherein said liquid fluid reservoir provides a continuous flow of liquid to the micro-machined channels, and said liquid traverses said channels by gravity flow.

16. The device of Claim 14, wherein said liquid fluid reservoir provides a continuous flow of liquid to the micro-machined channels, said liquid traverses said channels by capillary action.

17. The device of Claim 12, wherein said particulate charging member comprises a plurality of adjacent high voltage wires alternating with a plurality of ground wires, and positioned such that the gaseous fluid stream passes through between the plurality of such wires.

18. An electrostatic precipitator device to remove charged particulate matter from a moving gaseous fluid stream, said device providing a continuous voltage applied to a plurality of high voltage plates therein, said device comprising:

a. a plurality of collector ground plates alternating with the high voltage plates;

b. a plurality of micro-channels machined on each side of the collector ground plates; and

c. a liquid reservoir providing liquid to the plurality of micro-channels.

19. The device of Claim 18, wherein said liquid traverses said micro-channels by capillary action.

20. An electrostatic precipitator device to remove charged particles from a moving gaseous fluid stream, said device providing a continuous voltage applied to a plurality of high voltage plates therein, said device comprising:

a. a plurality of collector ground plates alternating with the high voltage plates;

b. a plurality of micro-channels machined on each side of the collector ground plates;

c. a liquid reservoir providing liquid to the plurality of micro-channels;

d. an analytical device to continuously analyze the particles collected in the liquid.

21. A method of using an electrostatic precipitator device to separate and collect particulate matter contained in a moving gaseous fluid stream, said method comprising the steps of:

a. providing the gaseous fluid stream to flow through the device;

b. imparting a voltage to a plurality of planar high voltage electrode plates;

c. alternating the high voltage electrode plates with a plurality of planar collector ground plates;

d. providing a liquid over each planar surface of the collector ground plates; and

e. collecting the particulate matter in the liquid.

22. The method of Claim 21, further comprising the step of imparting a voltage to the particulate matter contained in the fluid stream.

23. The method of Claim 21, further comprising the step of micro-machining a plurality of channels in each planar surface of the collector ground plate.

24. The method of Claim 23, further comprising the step of providing the liquid to flow through the plurality of channels.

25. The method of Claim 24, further comprising the step of providing the liquid to flow through the plurality of channels by gravity.

26. The method of Claim 24, further comprising the step of providing the liquid to flow through the plurality of channels by capillary action.

27. The method of Claim 21, further comprising the step of providing the liquid in the form of water.

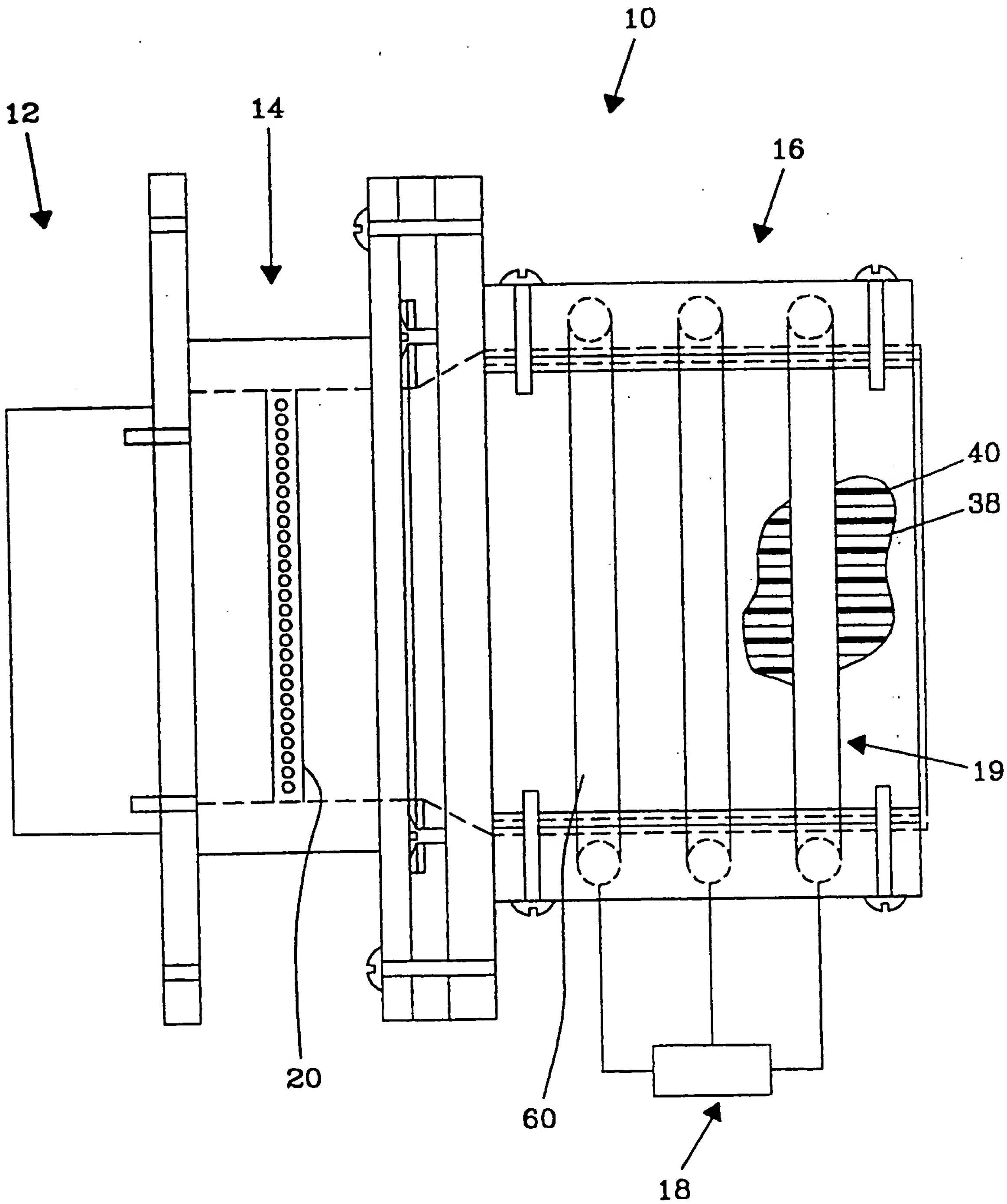


Fig. 1

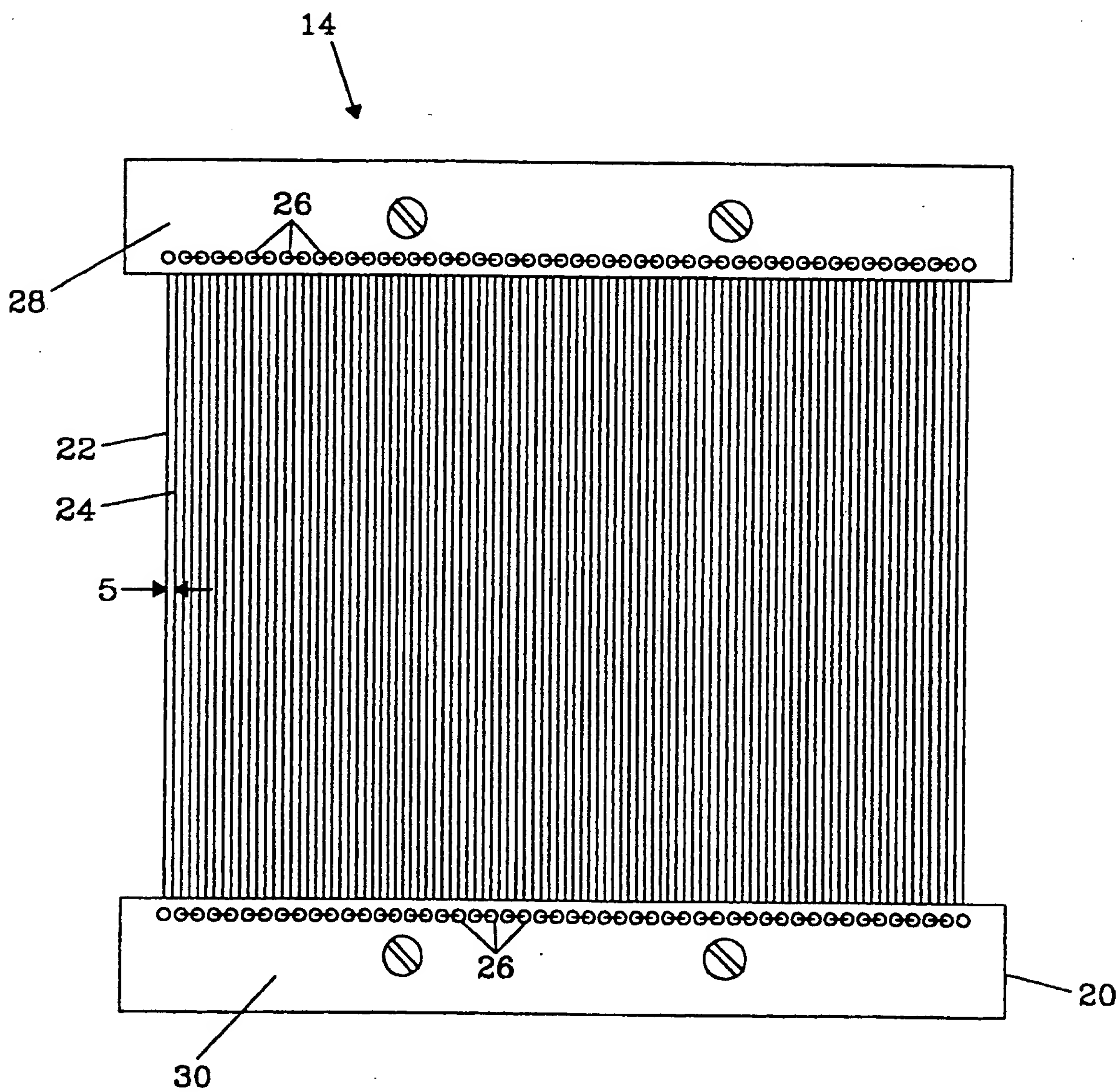
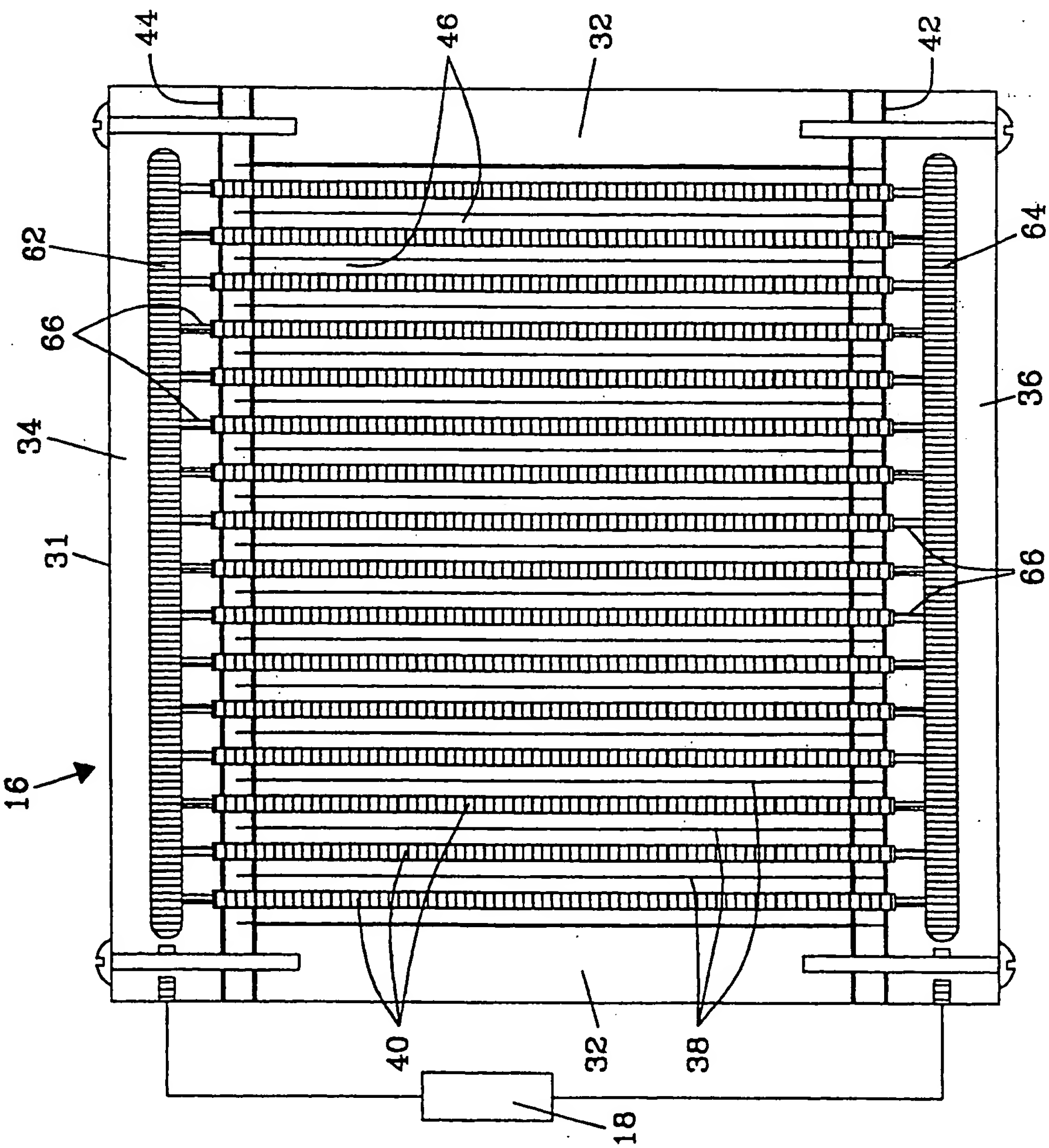


Fig. 2

Fig. 3



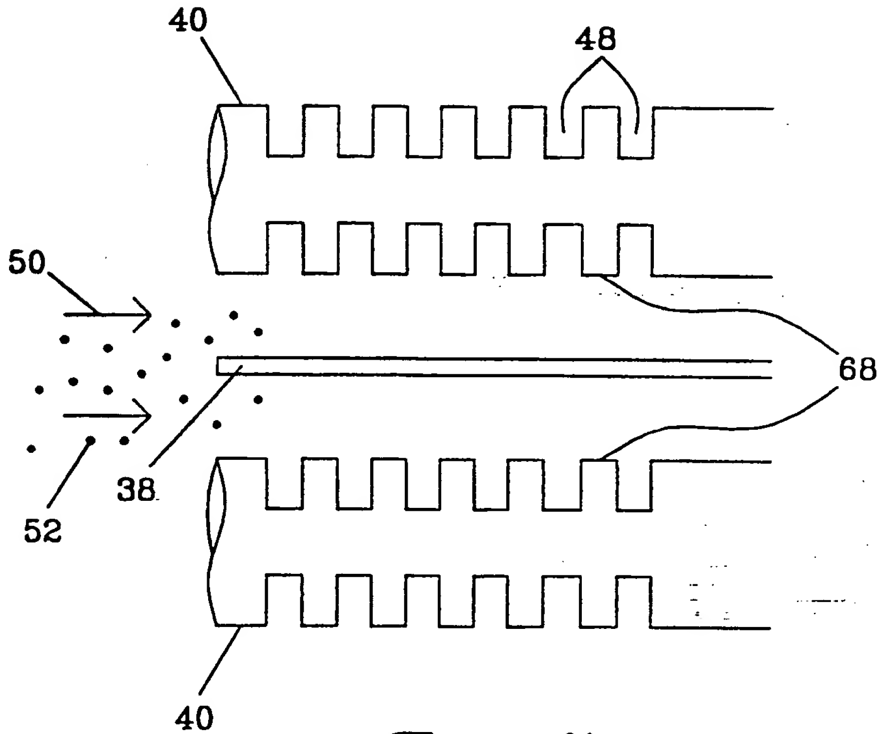


Fig. 4

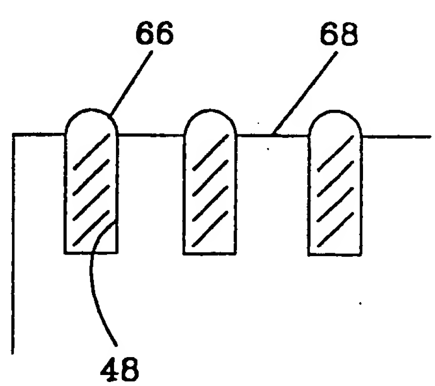


Fig. 5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/12596

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B03C3/53

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B03C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 4 553 987 A (ARTAMA ARVI ET AL) 19 November 1985 see column 2, line 24 - column 4, line 11; claim 1; figures 1-5	1-4,6,8, 21,22,27 12,17,18
A	US 3 248 857 A (K.WEINDEL ET AL) 3 May 1966 see column 2, line 18-46; claims 1,6; figures 1,3	1,5,6, 21,23-26

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 August 1998	04/09/1998
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Decanniere, L

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 98/12596

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 4553987	A	19-11-1985	NONE	
US 3248857	A	03-05-1966	NONE	